Defense Technical Information Center Compilation Part Notice

ADP013933

TITLE: Radar Cross Section of a Perfectly Conducting, Flat, Polygonal Plate Over a Dielectric, Lossy Half Space: A Closed Form, Physical Optics Expression

DISTRIBUTION: Approved for public release, distribution unlimited

This paper is part of the following report:

TITLE: 2002 International Conference on Mathematical Methods in Electromagnetic Theory [MMET 02]. Volume 2

To order the complete compilation report, use: ADA413455

The component part is provided here to allow users access to individually authored sections of proceedings, annals, symposia, etc. However, the component should be considered within the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP013889 thru ADP013989

RADAR CROSS SECTION OF A PERFECTLY CONDUCTING, FLAT, POLYGONAL PLATE OVER A DIELECTRIC, LOSSY HALF SPACE: A CLOSED FORM, PHYSICAL OPTICS EXPRESSION

Hristos T. Anastassiu

Institute of Communication and Computer Systems, Department of Electrical and Computer Engineering, National Technical University of Athens,
Iroon Polytechniou 9, GR-15780 Zografou, GREECE
e-mail: hristosa@esd.ece.ntua.gr Tel.: +3010 7722466 FAX: +3010 7723557

ABSTRACT

The Physical Optics approximation is employed in the derivation of a closed form expression for the Radar Cross Section (RCS) of a flat, polygonal, perfectly conducting (PEC) plate, located over a dielectric, possibly lossy half space. The well-known "four-path model" is invoked in a first order approximation of the half space contribution to the scattering mechanisms. Numerical results are successfully compared to a reference, Moment Method solution. The analytical expressions derived can facilitate very fast RCS calculations for realistic scatterers, such as ships in a sea environment, or aircraft flying low over the ground.

INTRODUCTION

Radar Cross Section (RCS) estimation of electrically large, complex targets is usually performed via high frequency techniques, such as Physical Optics (PO). A target of complex geometry is routinely decomposed into an aggregate of elementary surfaces, and the total scattered field is computed as a superposition of the elementary scattering contributions. Since the simplest possible shape of an elementary patch is a flat polygon, accurate RCS calculation for such a geometry is extremely important. Most papers in the literature are related to RCS calculations in free space, which is not a realistic situation in several cases, such as a floating ship, or a low – flying aircraft. RCS analysis in the presence of a half space can be performed via use of the "four-path model" [1]-[3], yielding good results for special geometries, e.g. [4]. The purpose of this paper is to extend Gordon's [5] important PO analytical expressions for the RCS of a flat, PEC, polygonal plate, so that they are valid in the presence of a dielectric, possibly lossy half space. The objective of such a work is the reduction of the computational cost associated with RCS calculations of electrically large, complex targets in the presence of sea or ground, since utilization of a closed form PO expression implies avoidance of time-consuming, numerical, surface integrations.

MATHEMATICAL ANALYSIS

The geometry of the problem to be analyzed (Fig.1) consists of a PEC, polygonal, flat plate with Q vertices, vanishing thickness, located over a half space, which is filled with a dielectric, possibly lossy material of relative electric permittivity ε_r and conductivity

σ. The half space is assumed to lie in the far field region of the polygonal plate. The interface between free space and dielectric is assumed to lie at the z=0 plane. A spherical coordinate system (r, θ, ϕ) is defined as shown in the figure. The images of the associated unit vectors with respect to the half space boundary are denoted by subscript "r" in Fig. 1. A plane wave illuminates the plate target, impinging from an elevation angle θ. In order to simulate the half space effects in a simple fashion, the well-known "four-path model" [1]-[3] is invoked. Assuming ray optical behaviour of the fields, the total backscattered field can be expressed as a cumulative result of four separate mechanisms (see Fig.2). Although the four-path model is not exact, it yields accurate results under certain limitations [3]. To apply the four-path model in the problem, the general, far field expression for the PO scattered field is utilized four times. Summing all contributions, the monostatic RCS $\sigma_{HH,VV}$ of the flat plate is finally expressed as

$$\begin{Bmatrix}\sigma_{HH}\\ \sigma_{VV}\end{Bmatrix}=\frac{k^2}{\pi}\left|\hat{\mathbf{r}}\cdot\hat{\mathbf{n}}I(2\hat{\mathbf{r}})+(\hat{\mathbf{r}}+\hat{\mathbf{r}}_r)\cdot\hat{\mathbf{n}}I(\hat{\mathbf{r}}+\hat{\mathbf{r}}_r)\begin{Bmatrix}R_H\\ R_V\end{Bmatrix}+\hat{\mathbf{r}}_r\cdot\hat{\mathbf{n}}I(2\hat{\mathbf{r}}_r)\begin{Bmatrix}R_H^2\\ R_V^2\end{Bmatrix}\right|^2 \tag{1}$$

where the upper line is valid for horizontal, and the lower for vertical polarization, R_H and R_V are the respective Fresnel reflection coefficients for the half space and $\hat{\boldsymbol{n}}$ is the unit vector normal to the plate, whereas

$$I(\mathbf{v})=\frac{j}{k(\mathbf{v}-\mathbf{v}\cdot\hat{\mathbf{n}}\hat{\mathbf{n}})^2}\sum_{q=1}^{Q}\mathbf{v}\times\hat{\mathbf{n}}\cdot(\mathbf{r}_{q+1}-\mathbf{r}_q)\operatorname{sinc}\left[\frac{k}{2}\mathbf{v}\cdot(\mathbf{r}_{q+1}-\mathbf{r}_q)\right]\exp\left\{\frac{jk}{2}\mathbf{v}\cdot(\mathbf{r}_{q+1}+\mathbf{r}_q)\right\} \tag{2}$$

where, by definition, $\boldsymbol{r}_q$ is the location of the q^{th} vertex, $\boldsymbol{r}_{Q+1}\equiv\boldsymbol{r}_1$ and $\boldsymbol{v}$, $\hat{\boldsymbol{n}}$ are not parallel to each other. If $\boldsymbol{v}$, $\hat{\boldsymbol{n}}$ are parallel to each other, (2) is not valid, but reduces to

$$I(\boldsymbol{v})=A\exp\{jk\boldsymbol{v}\cdot\boldsymbol{r}_0\} \tag{3}$$

where A is the area of the polygon and $\boldsymbol{r}_0$ is an arbitrary point on its surface. It should be pointed out that (1) was derived under the PO assumption that both sides of the plate can be illuminated, either by the direct or by the reflected wave.

NUMERICAL RESULTS

The expression in (1) was validated via comparisons with reference Moment Method (MoM) results [6]. A square, PEC, 2λ by 2λ flat plate was located vertically, in the yz plane, over a half space (Fig. 3), with relative permittivity ε_r=80-j70 (simulating sea water). The center of the plate was located at a distance d=10λ from the interface. The RCS results at the ϕ=0 cut, as a function of the θ angle, and for horizontal polarization are depicted in Fig. 4, showing excellent agreement, for a wide range of elevation angles. For θ angles closer to 0, the agreement is expectedly not as good, since the PO approximation fails in the region of grazing incidence.

REFERENCES

[1] Knott, E. F., J. F. Schaeffer and M. T. Tuley, *Radar Cross Section*, Artech House, Boston/London, 1993.

[2] Fabbro, V., "Three-dimensional backscattering by a target above the sea surface", *Electromagnetics*, 21(6), pp. 451-466, Sep. 2001.

[3] Johnson, J. T., "A study of the four-path model for scattering from an object above a half space", *Microwave and Optical Technology Letters*, 30(2), pp. 130-134, July 2001.

[4] Sarkar, T. K. and R. F. Harrington, "RCS of conducting bodies over a lossy half space", *Radio Science*, vol. 15, no. 3, pp. 581-585, May-June 1980.
[5] Gordon, W. B., "Far – field approximations to the Kirchhoff – Helmholtz representations of scattered fields", *IEEE Transactions on Antennas and Propagation*, vol. 23, pp. 590-592, 1975.
[6] Burkholder, R. J., personal communication, Feb. 2002.

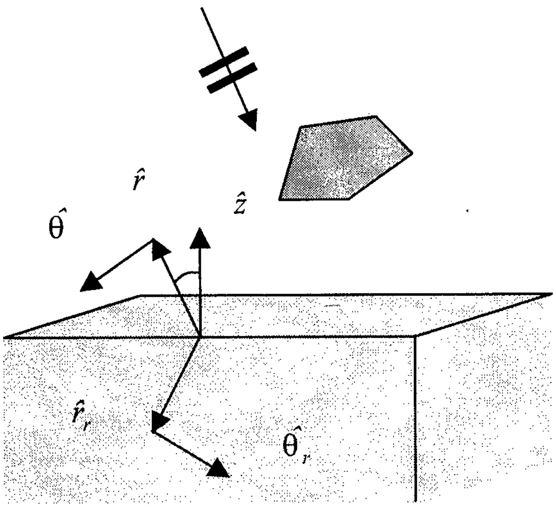

Fig. 1. Geometry of the problem

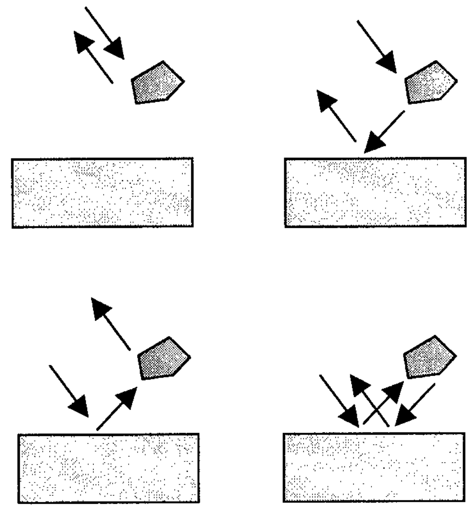

Fig. 2. The four path model

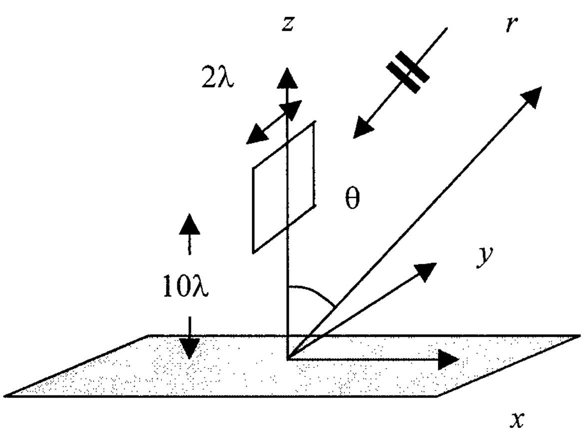

Fig. 3. A vertically oriented PEC square plate

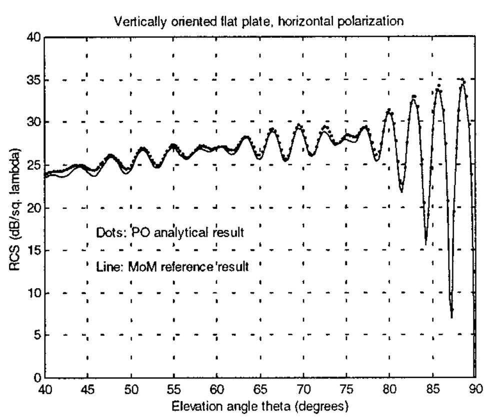

Fig. 4. Monostatic RCS plot for the configuration of Fig. 3 (ϕ=0 cut, horizontal polarization)